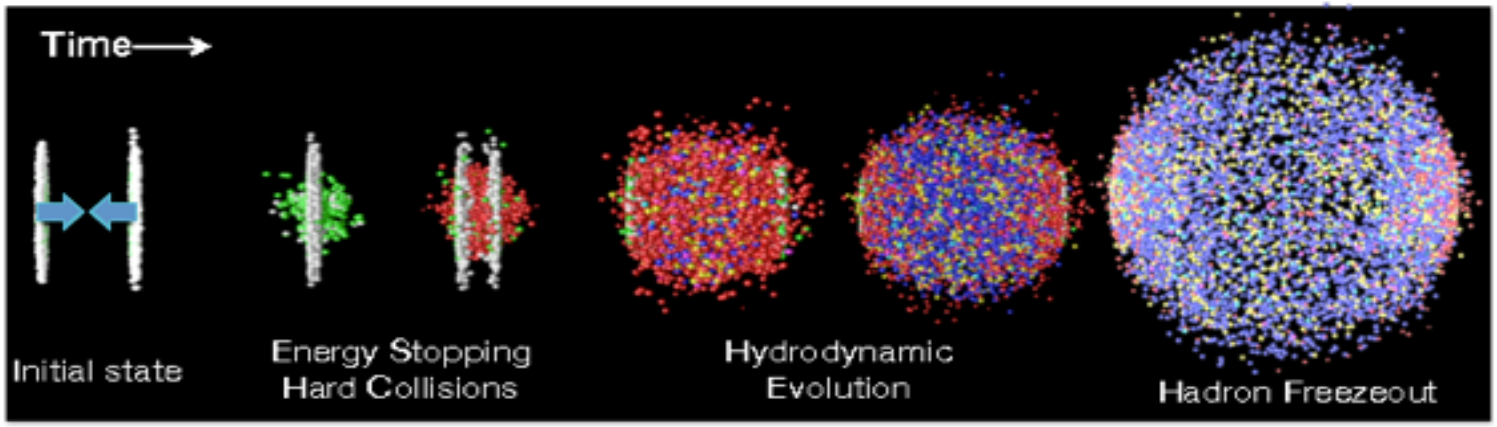
ϕ Meson Measurements at Forward/Backward Rapidity at RHIC with PHENIX Detector

XIAOCHUN HE
GEORGIA STATE UNIVERSITY
FOR THE PHENIX COLLABORATION

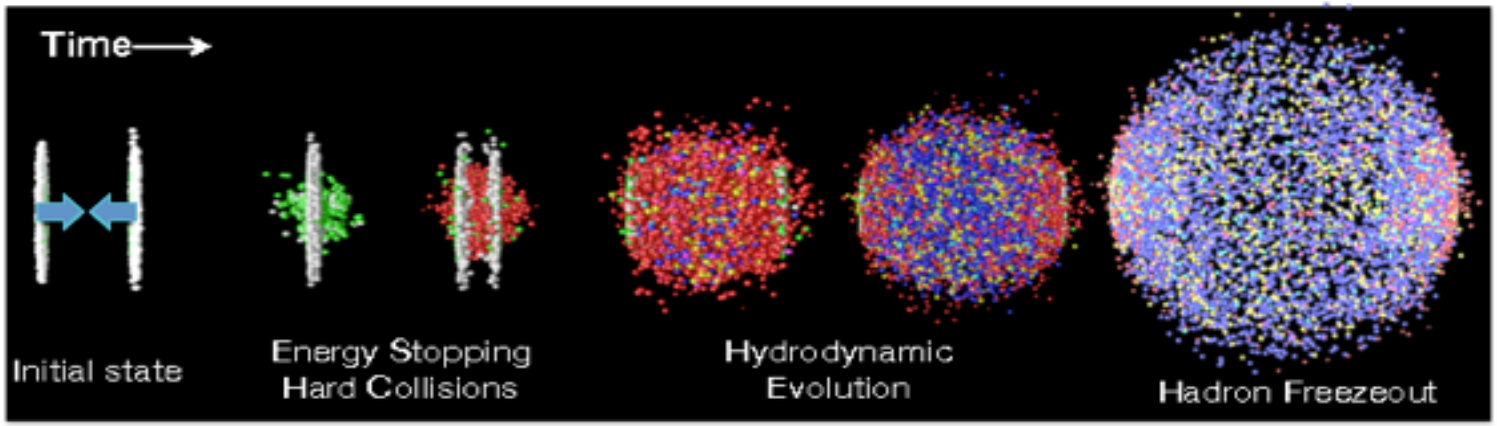
Why Is This Work Interesting?

The forefront effort in high energy nuclear physics community over the past three decades is to create and characterize the properties of the quark-gluon plasma in relativistic heavy ion collisions. Extensive results have been produced both from the RHIC and the LHC experiments.



Why Is This Work Interesting?

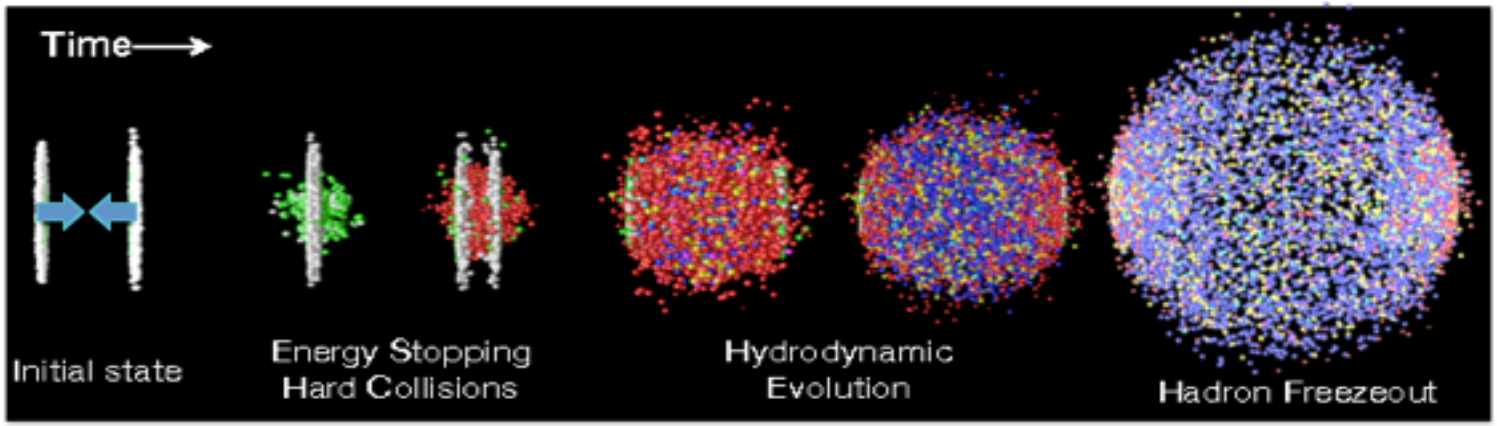
The forefront effort in high energy nuclear physics community over the past three decades is to create and characterize the properties of the quark-gluon plasma in relativistic heavy ion collisions. Extensive results have been produced both from the RHIC and the LHC experiments.



- It is well known that the medium created in heavy ion collisions is **HOT/ DENSE** and it **FLOWS** collectively at partonic (quarks and gluons) level.

Why Is This Work Interesting?

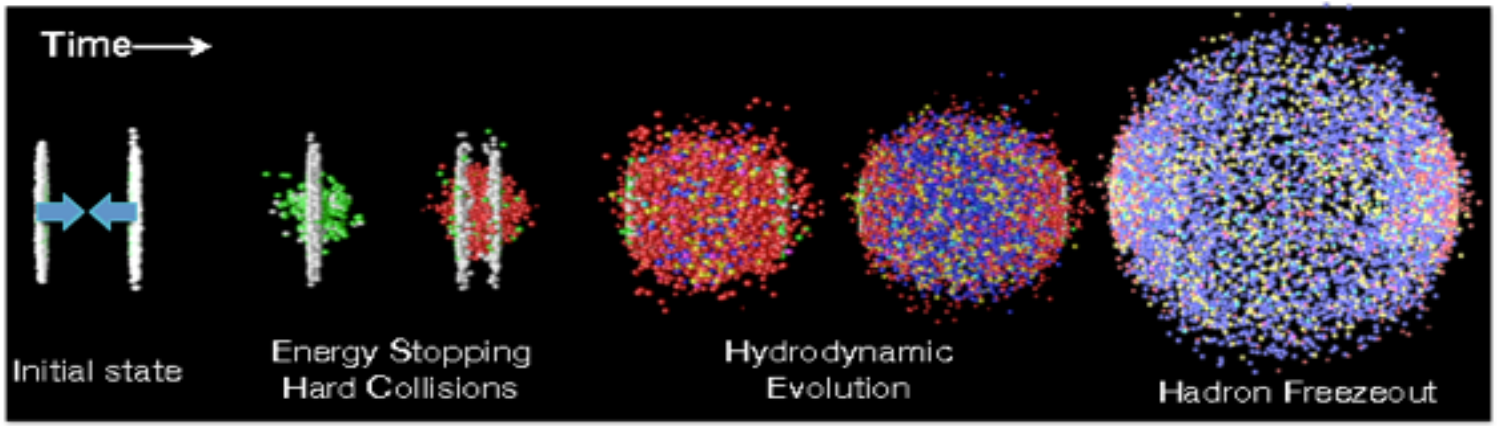
The forefront effort in high energy nuclear physics community over the past three decades is to create and characterize the properties of the quark-gluon plasma in relativistic heavy ion collisions. Extensive results have been produced both from the RHIC and the LHC experiments.



- It is well known that the medium created in heavy ion collisions is **HOT/ DENSE** and it **FLOWS** collectively at partonic (quarks and gluons) level.
- There are great successes of probing the medium properties with heavy quarks (charm and beauty) and jets, together with theoretical studies based on perturbative quantum chromodynamics (QCD).

Why Is This Work Interesting?

The forefront effort in high energy nuclear physics community over the past three decades is to create and characterize the properties of the quark-gluon plasma in relativistic heavy ion collisions. Extensive results have been produced both from the RHIC and the LHC experiments.



- It is well known that the medium created in heavy ion collisions is **HOT/ DENSE** and it **FLOWS** collectively at partonic (quarks and gluons) level.
- There are great successes of probing the medium properties with heavy quarks (charm and beauty) and jets, together with theoretical studies based on perturbative quantum chromodynamics (QCD).
- However, huge uncertainties still exist in understanding the soft particle production given the limited theoretical guidance (i.e. non-perturbative QCD regime). **More data is needed in order to constrain phenominological models**.

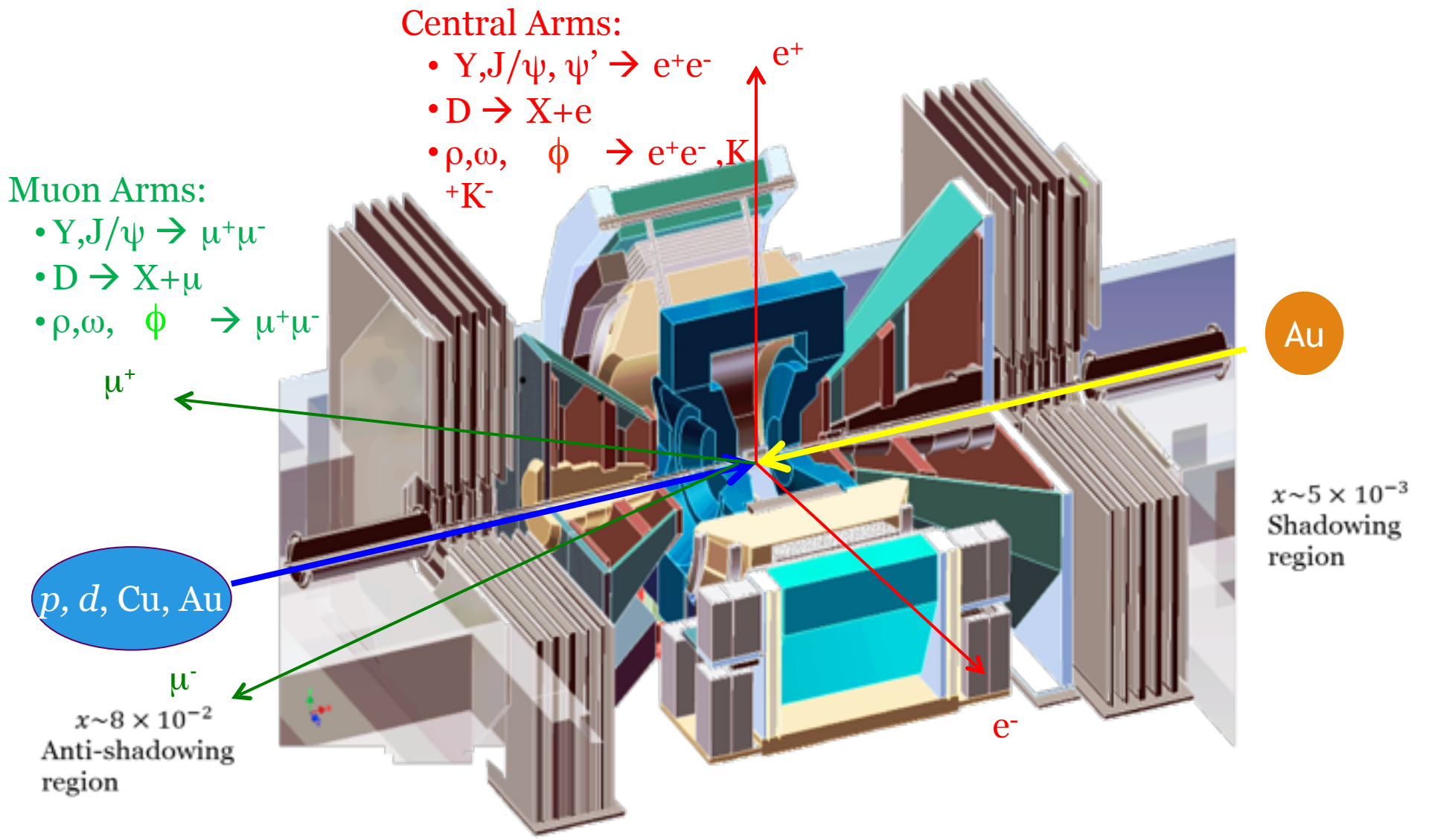
Outline

In this talk, I will start with a brief summary of ϕ measurements in central rapidity, which is then followed with **ϕ results (in dimuon decay channel) in the forward and backward rapidities in p+p, d +Au, Cu+Au collisions in the PHENIX experiment at RHIC**.

ϕ meson is an excellent probe for studying QGP (in Au+Au collisions) because it is sensitive to several aspects of the collision, including modifications of strangeness production in bulk matter. Owing to its small inelastic cross section for interacting with nonstrange hadrons, the ϕ meson is less affected by late hadronic rescattering and may reflect the initial evolution of the system.

The lepton decay channel is of particular interest because of the absence of strong interactions between muons and the surrounding hot hadronic matter.

PHENIX Detector

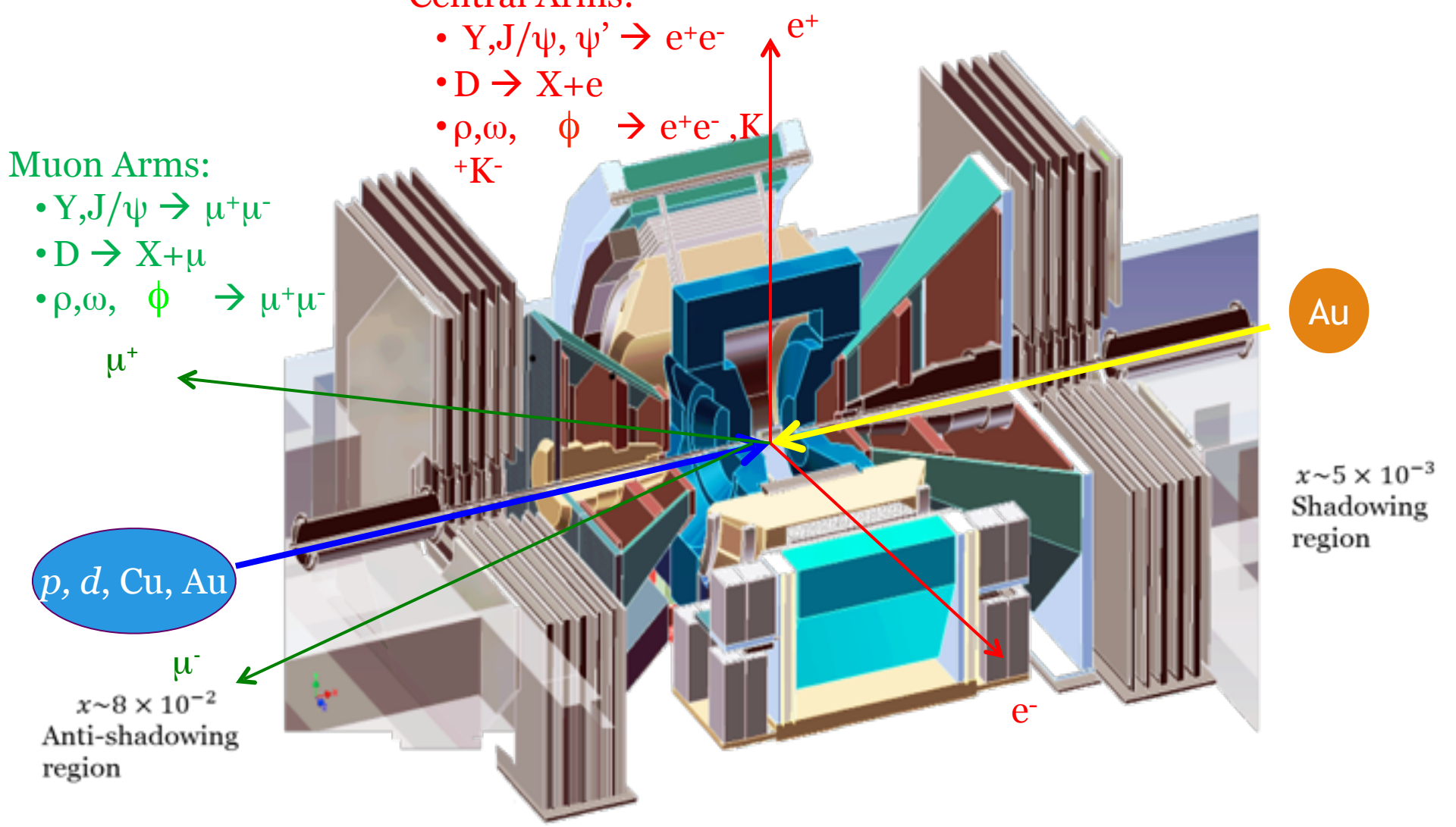


PHENIX Detector

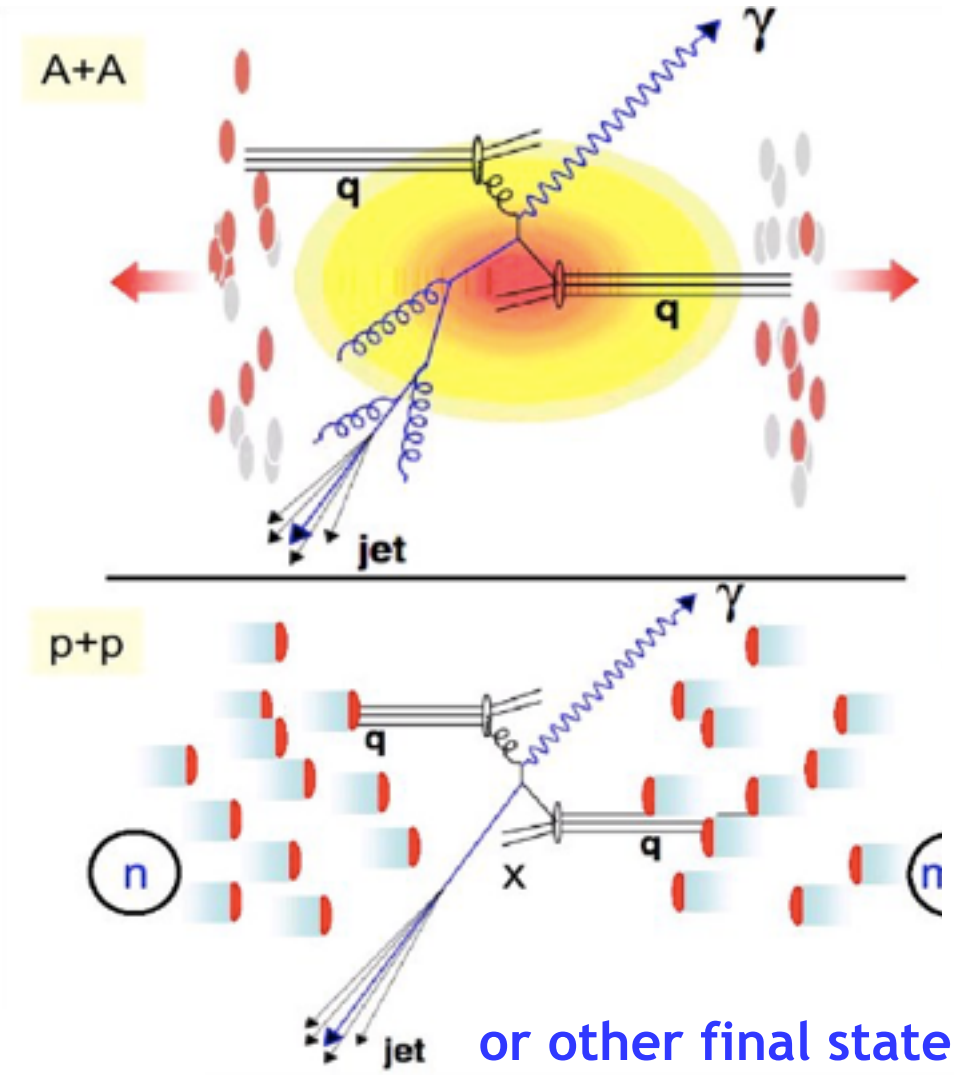
- Large rapidity coverage: $1.2<|y|<2.2$ and $|y|<0.35$
- PHENIX recorded p+p, p+Au, p+Al, d+Au, He+Au, Cu+Au and Au+Au collisions @ $\sqrt{s_{NN}}$ = 200 GeV and p+p collisions @ $\sqrt{s_{NN}}$ = 510 GeV.

Central Arms:
- $\Upsilon, J/\psi, \psi' \rightarrow e^+e^-$
- $D \rightarrow X+e$
- $\rho, \omega, \phi \rightarrow e^+e^-, K^+K^-$

Muon Arms:
- $\Upsilon, J/\psi \rightarrow \mu^+\mu^-$
- $D \rightarrow X+\mu$
- $\rho, \omega, \phi \rightarrow \mu^+\mu^-$

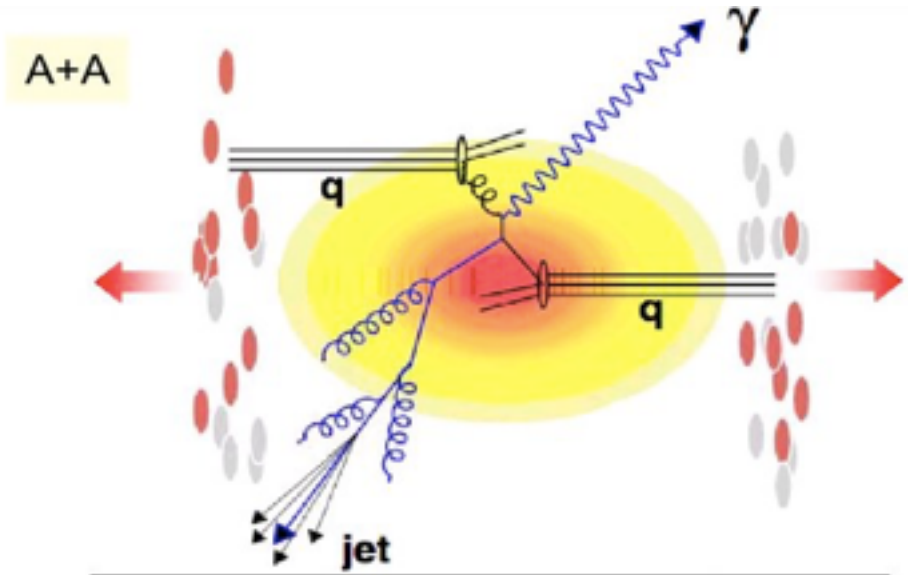


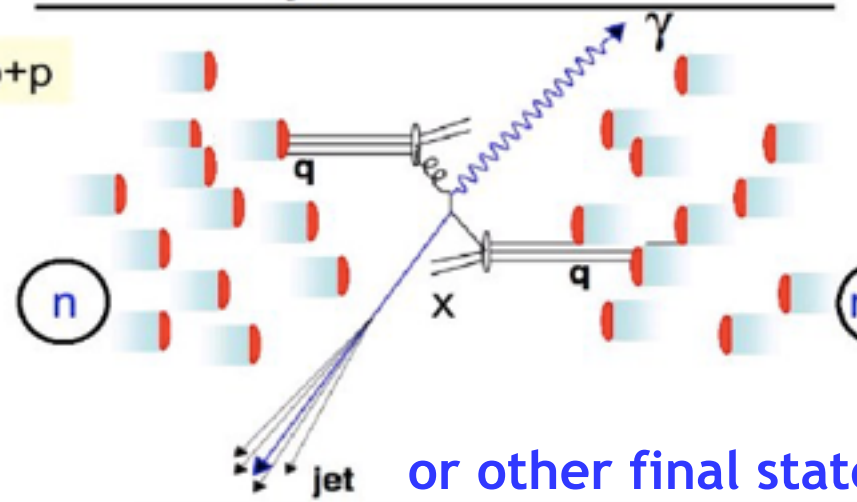
Nuclear Modification Factor – $R_{AA'}$

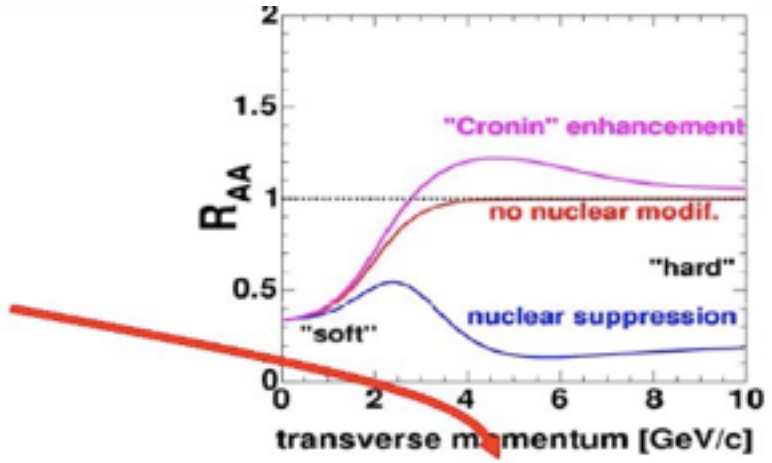


or other final state particles, like ϕ, π

Nuclear Modification Factor – $R_{AA'}$







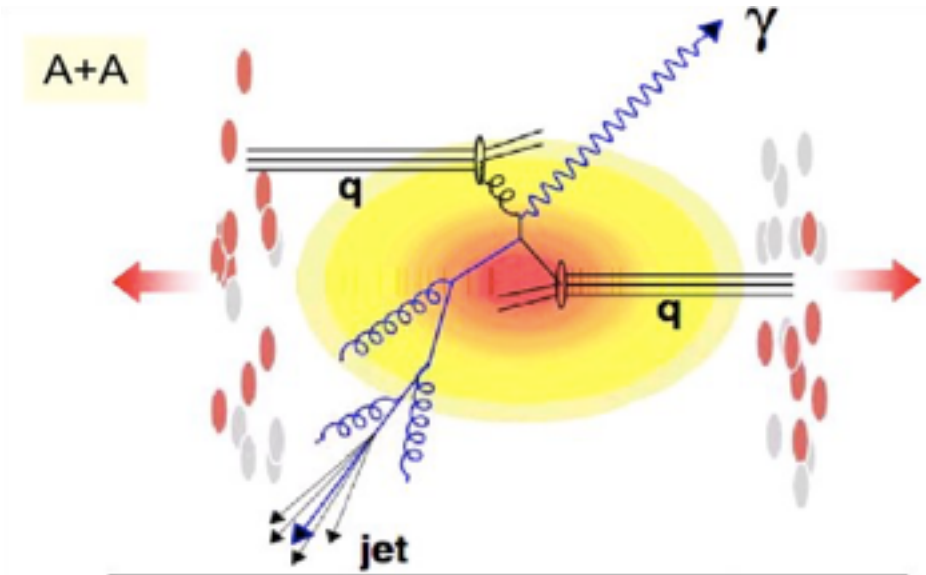
$$R_{AA} = \frac{d^2N_{AA}/dp_T dy}{\langle N_{binary}\rangle d^2N_{pp}/dp_T dy}$$

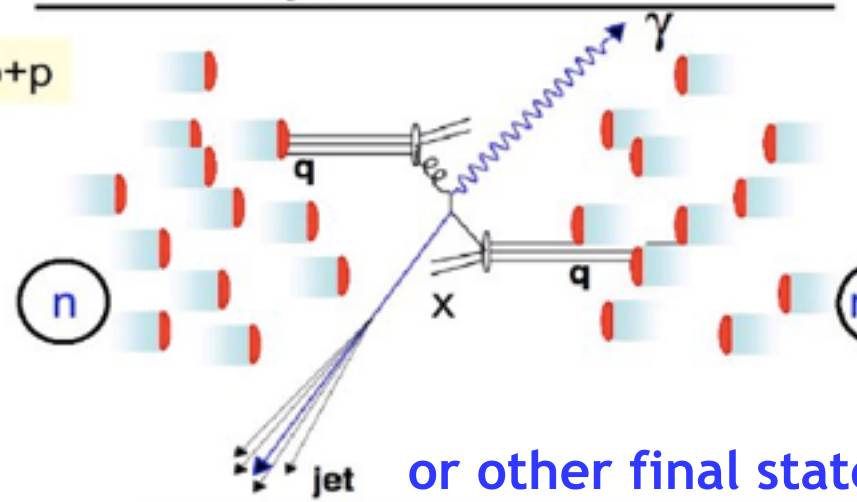
$\approx \langle N_{binary} \rangle$

varies with impact parameter ***b***

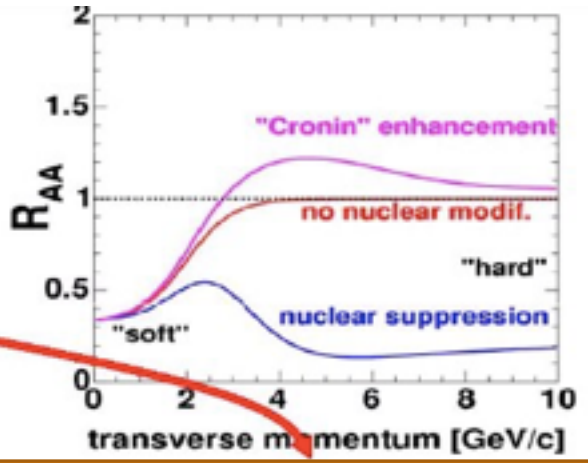
or other final state particles, like ϕ, π

Nuclear Modification Factor – $R_{AA'}$





$\approx \langle N_{binary} \rangle$

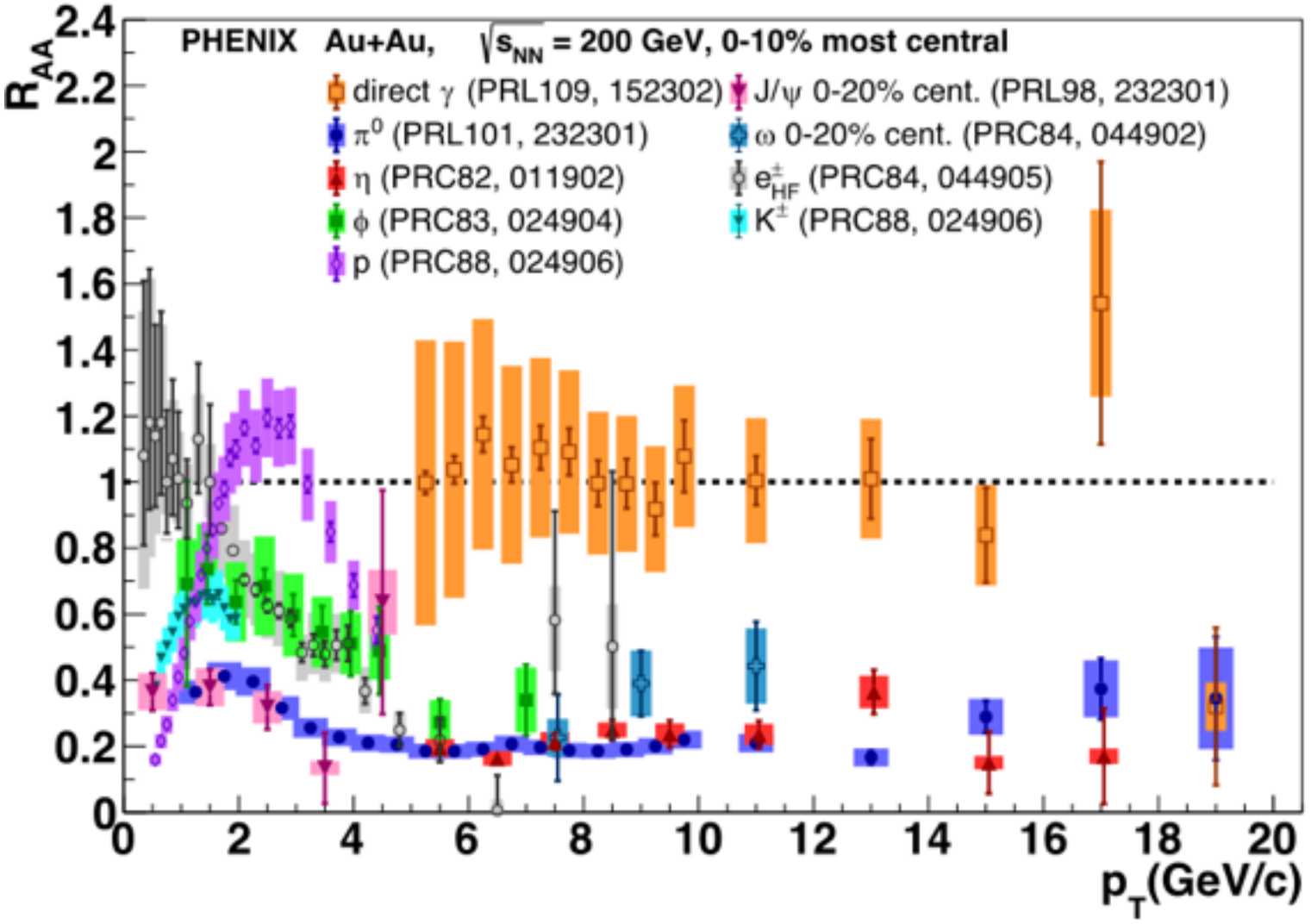


$$R_{AA} = \frac{d^2N_{AA}/dp_T dy}{\langle N_{binary} \rangle d^2N_{pp}/dp_T dy}$$

varies with impact parameter ***b***

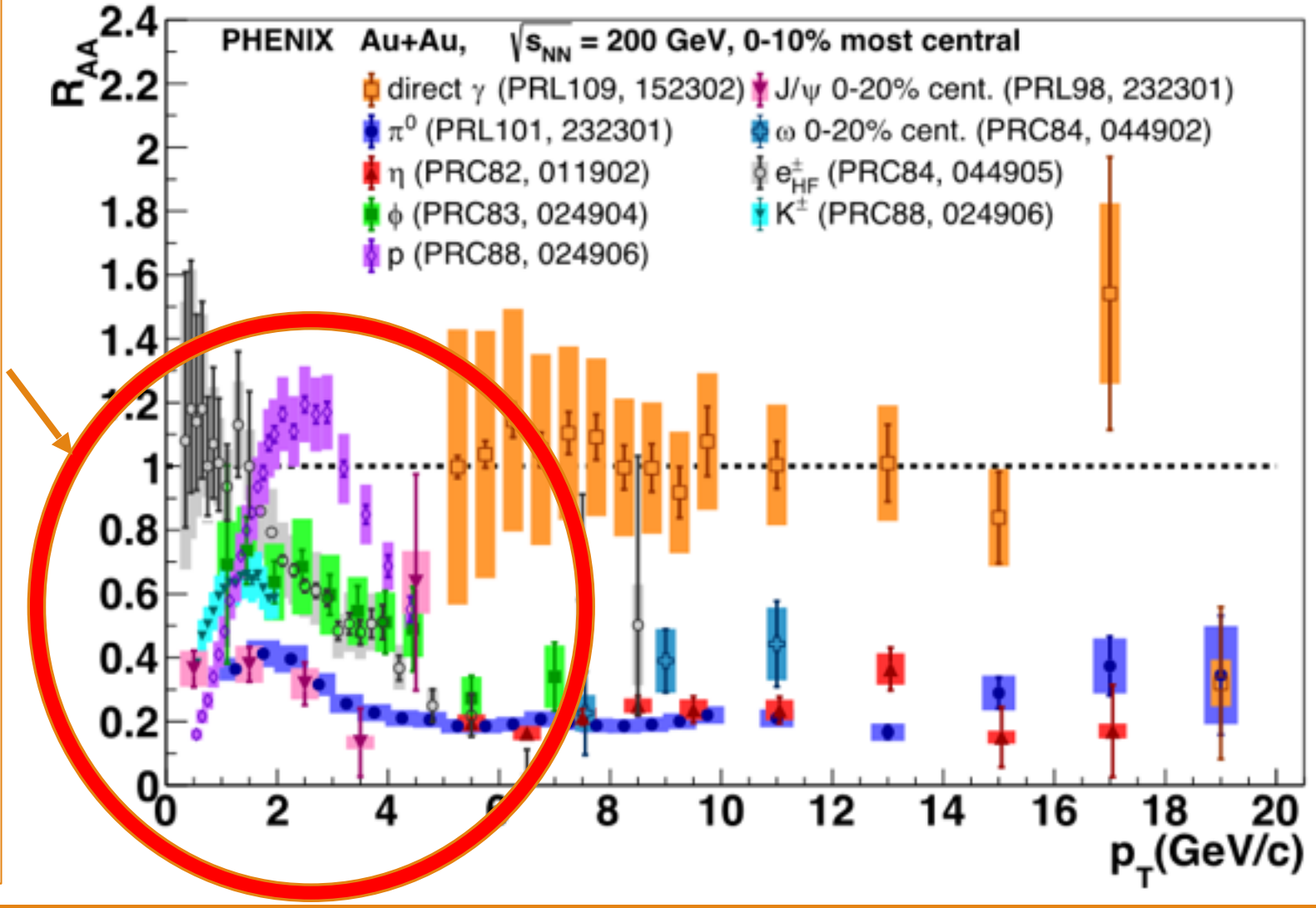
or other final state particles, like ϕ, π

Nuclear Modification Factors in the Most Central Au+Au Collision



Nuclear Modification Factors in the Most Central Au+Au Collision

QCD dynamics is very hard to study !!!



PHYSICAL REVIEW C **83**, 024909 (2011)

Nuclear modification factors of ϕ mesons in d + Au, Cu + Cu, and Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV

PHYSICAL REVIEW C **83**, 024909 (2011)

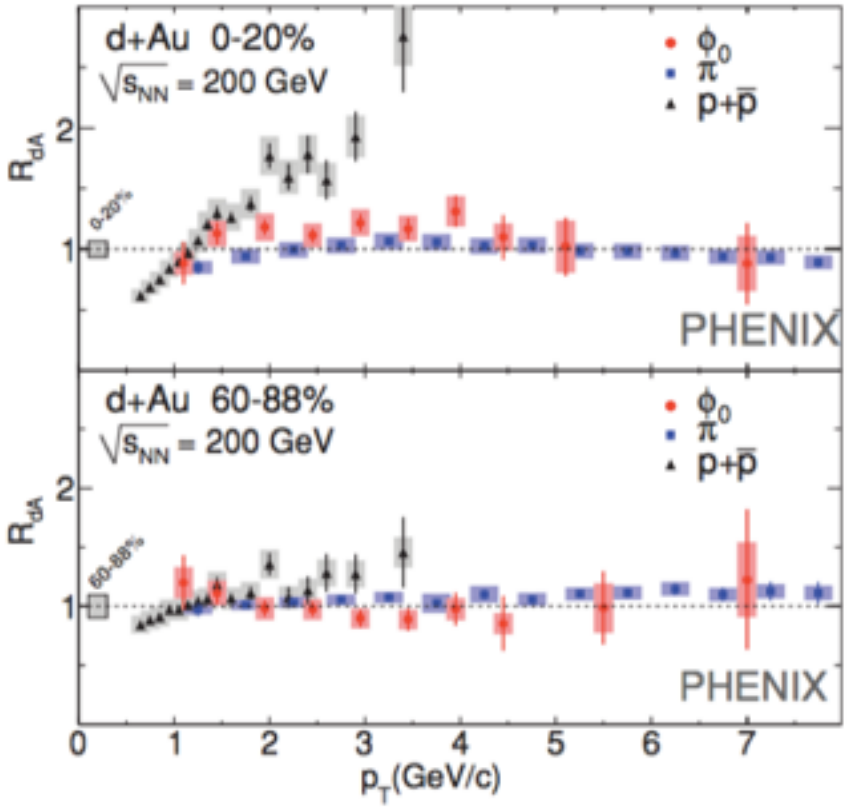
ϕ results in central rapidity

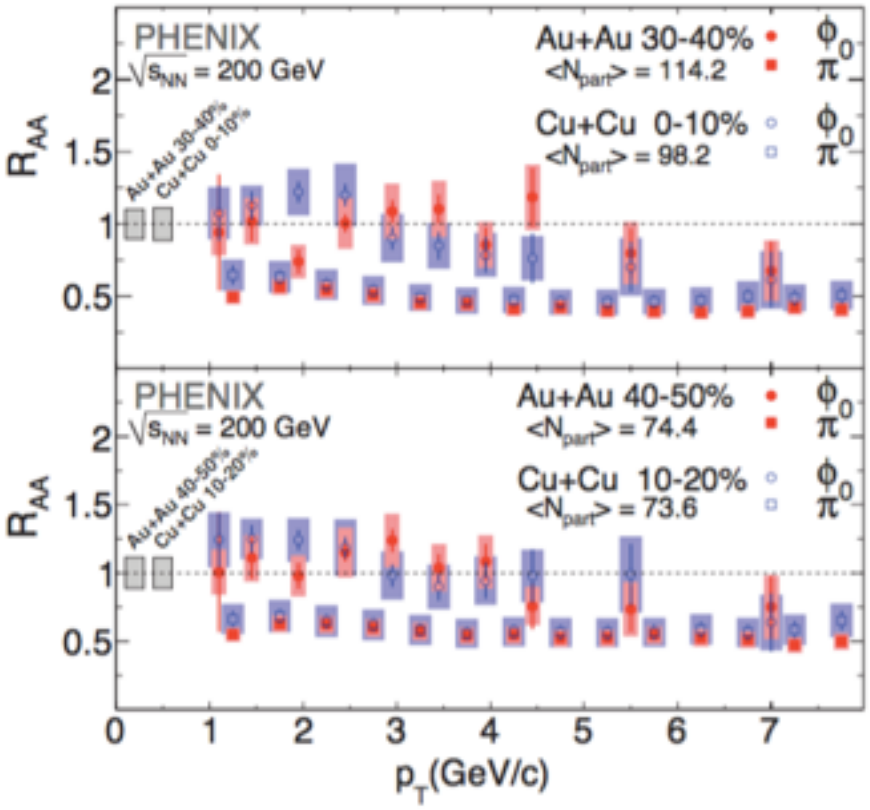
Nuclear modification factors of ϕ mesons in d + Au, Cu + Cu, and Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV

PHYSICAL REVIEW C 83, 024909 (2011)

ϕ results in central rapidity

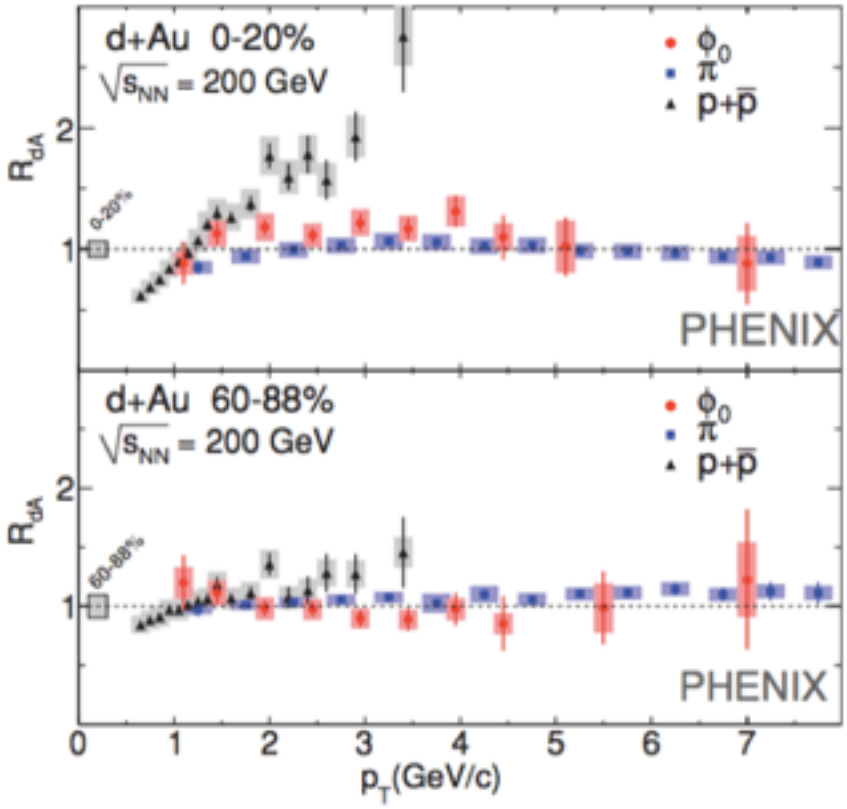
Nuclear modification factors of ϕ mesons in d + Au, Cu + Cu, and Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV

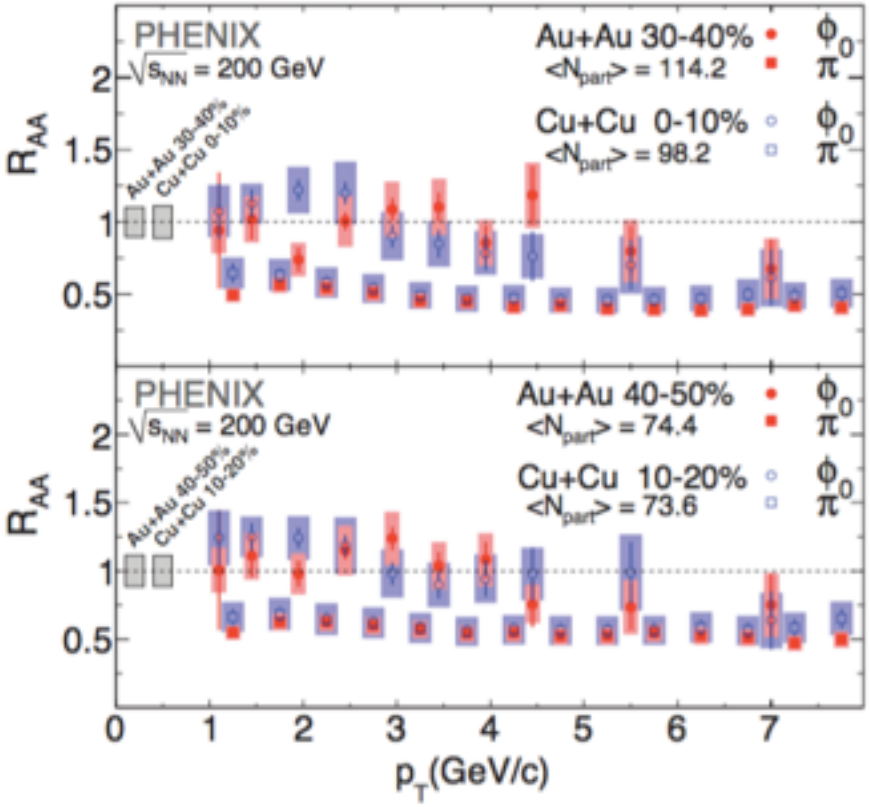




PHYSICAL REVIEW C 83, 024909 (2011)

Nuclear modification factors of ϕ mesons in d + Au, Cu + Cu, and Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV





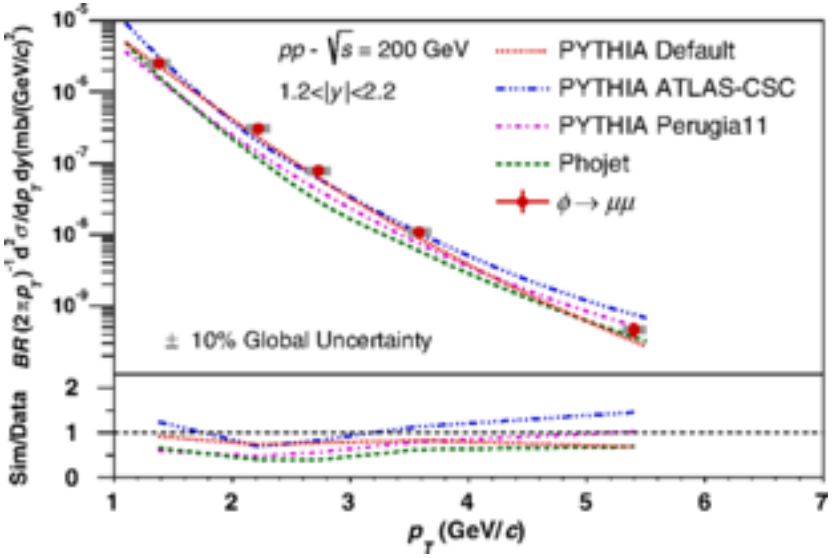
The ϕ meson exhibits a different suppression pattern compared to lighter mesons (π^0 and η) and baryons (protons and antiprotons) in heavy ion collisions. For all centralities, the ϕ meson is less suppressed than π^0 and η in the intermediate pT range (2–5 GeV/c), whereas, at higher pT , ϕ, π^0, and η show similar suppression values.

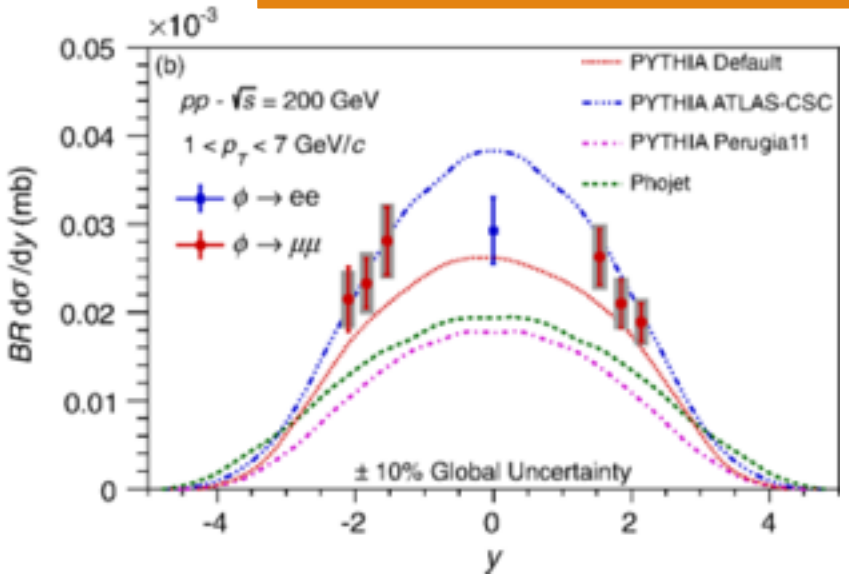
How about ϕ production in forward and backward rapidities?

RESULTS SHOULD BE VERY IMPORTANT TO CONSTRAINING THE THEORETICAL MODEL PREDICTIONS.

ϕ Meson Production in Forward/Backward Rapidity in p+p at 200 GeV

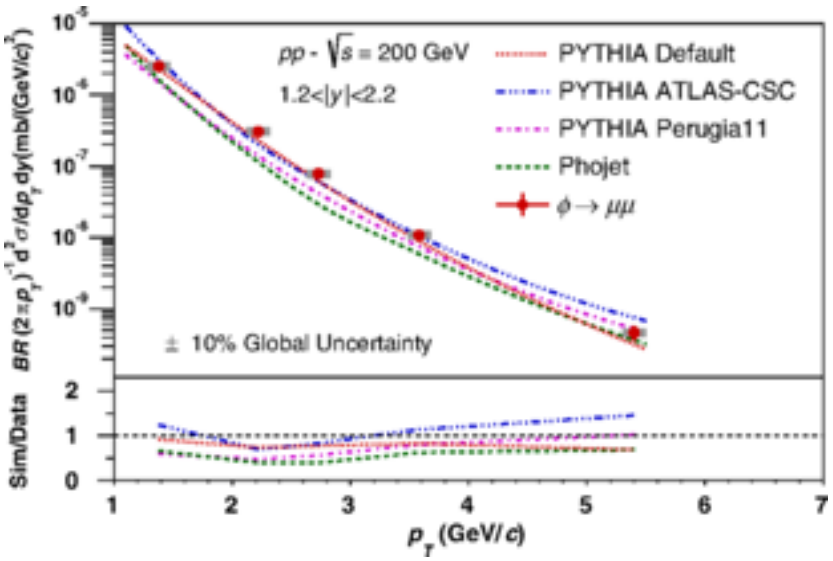
Phys. Rev. D **90**, 052002 (2014)

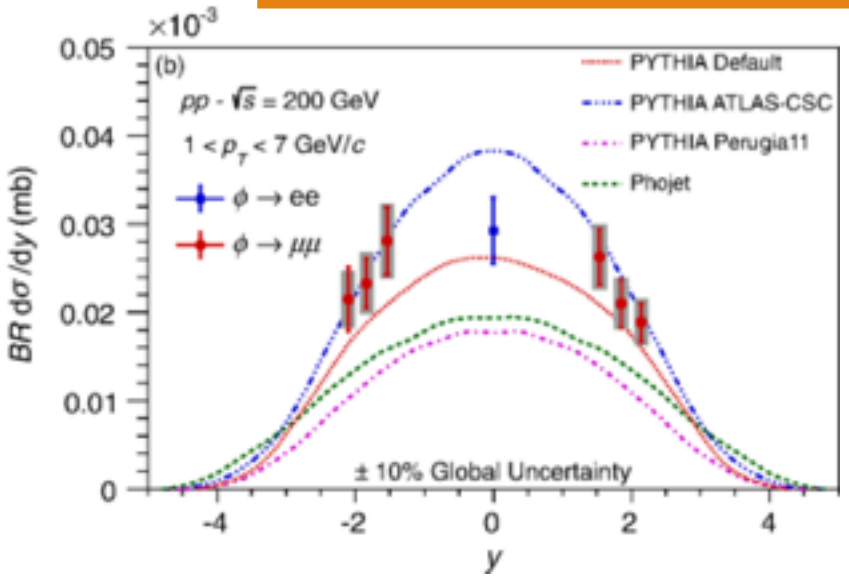




ϕ Meson Production in Forward/Backward Rapidity in p+p at 200 GeV

Phys. Rev. D **90**, 052002 (2014)

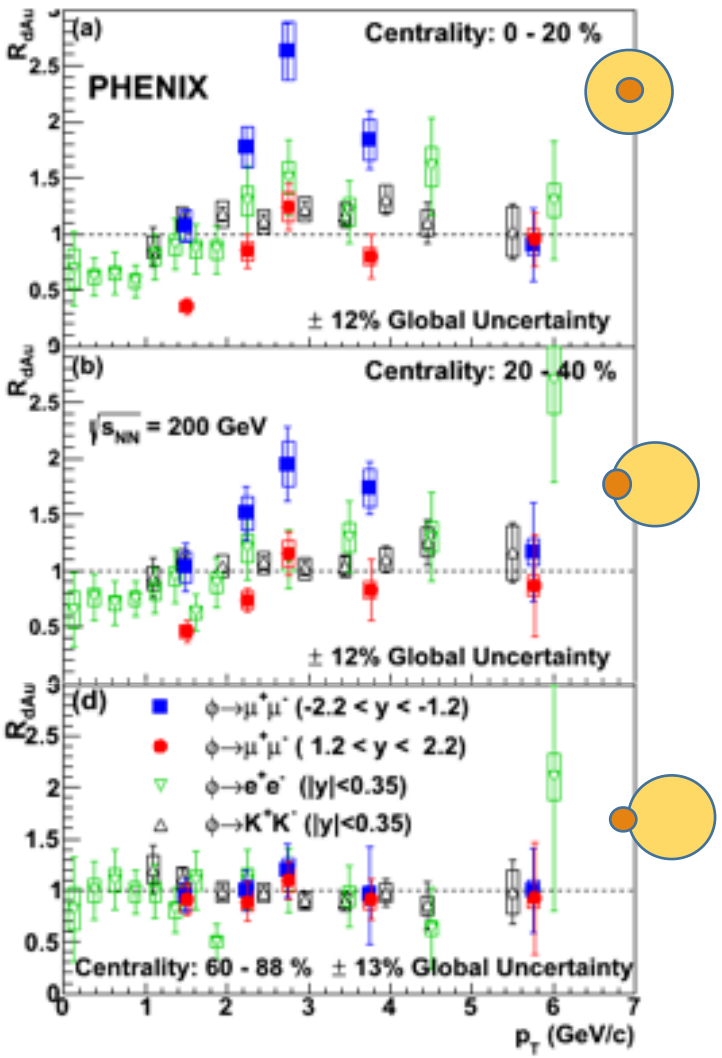




- Very important for validating the phenomenological models for strangeness production.
- Provide baseline measurement for studying nuclear modification of ϕ production in d+Au, p+Au,p+Al, Cu+Cu, Cu +Au and Au+Au collisions at RHIC.

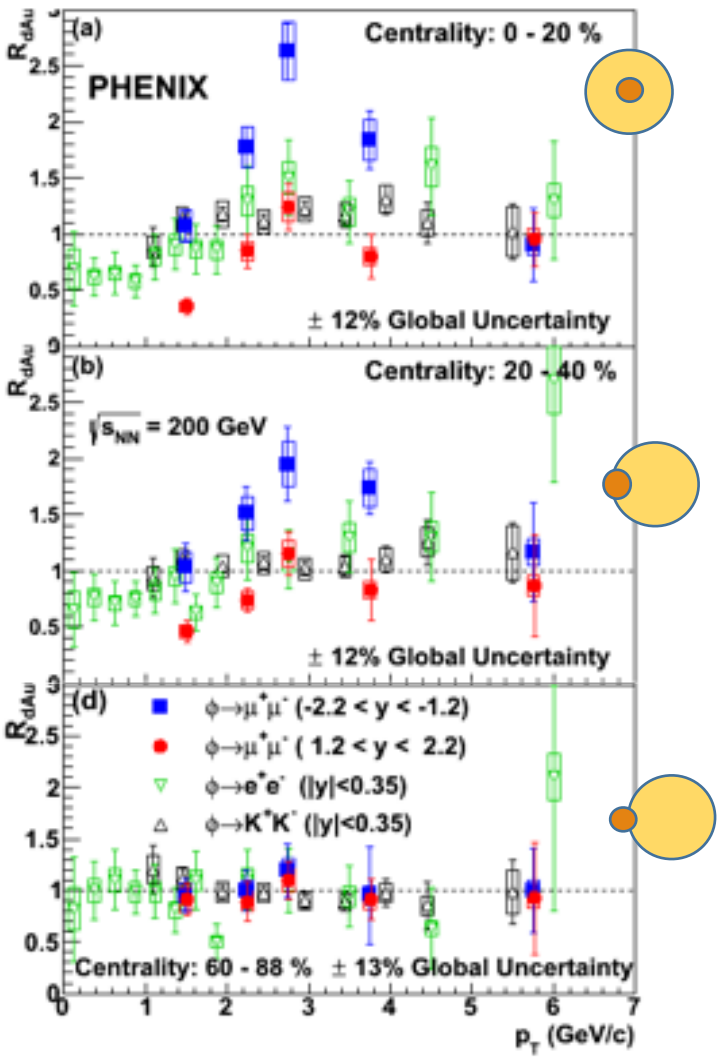
Nuclear Modification in d+Au

Phys. Rev. C **92**, 044909 (2015)



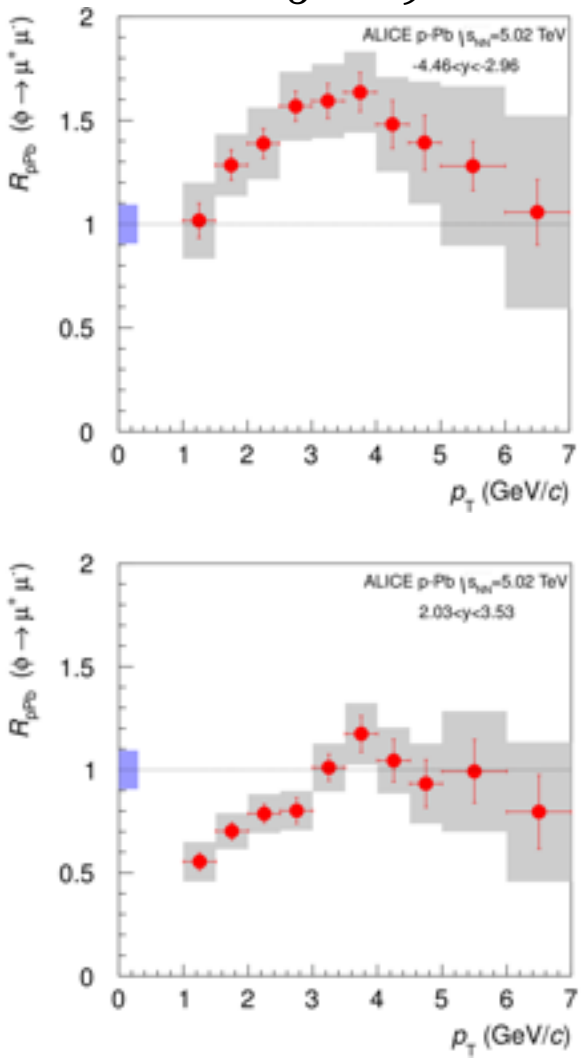
Nuclear Modification in d+Au

Phys. Rev. C **92**, 044909 (2015)



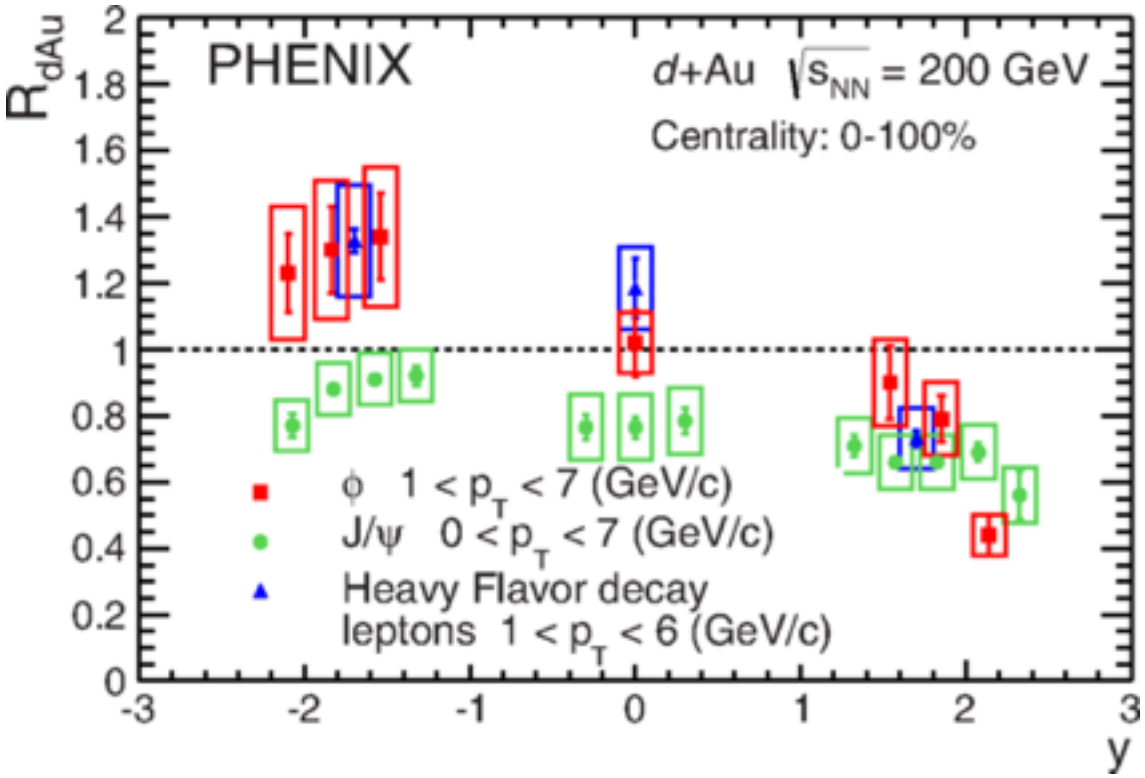
The R_{dAu} enhancement (suppression) in the Au-going (*d*-going) direction is consistent with what is observed by the ALICE collaboration at $\sqrt{s_{NN}}$= 5.02 TeV in *p*+Pb collisions

arXiv:1506.09206.



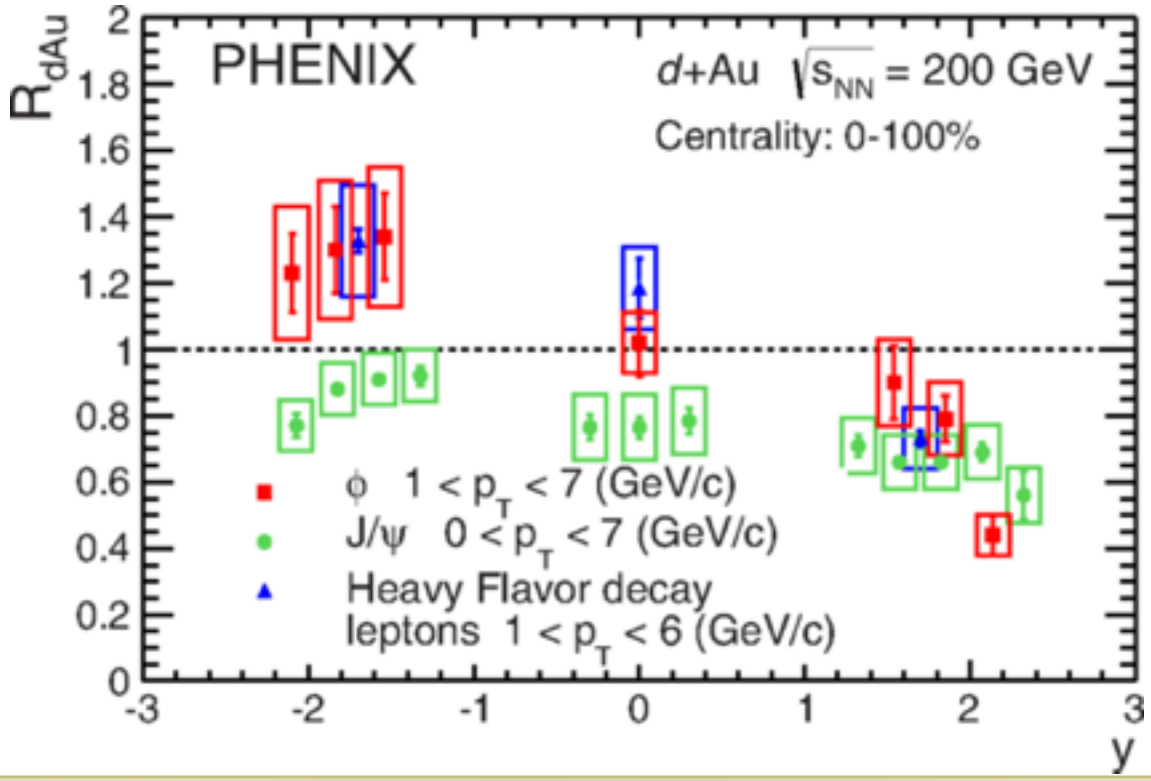
ϕ Meson vs Open & Closed Heavy Flavor

Phys. Rev. C **92**, 044909 (2015)



ϕ Meson vs Open & Closed Heavy Flavor

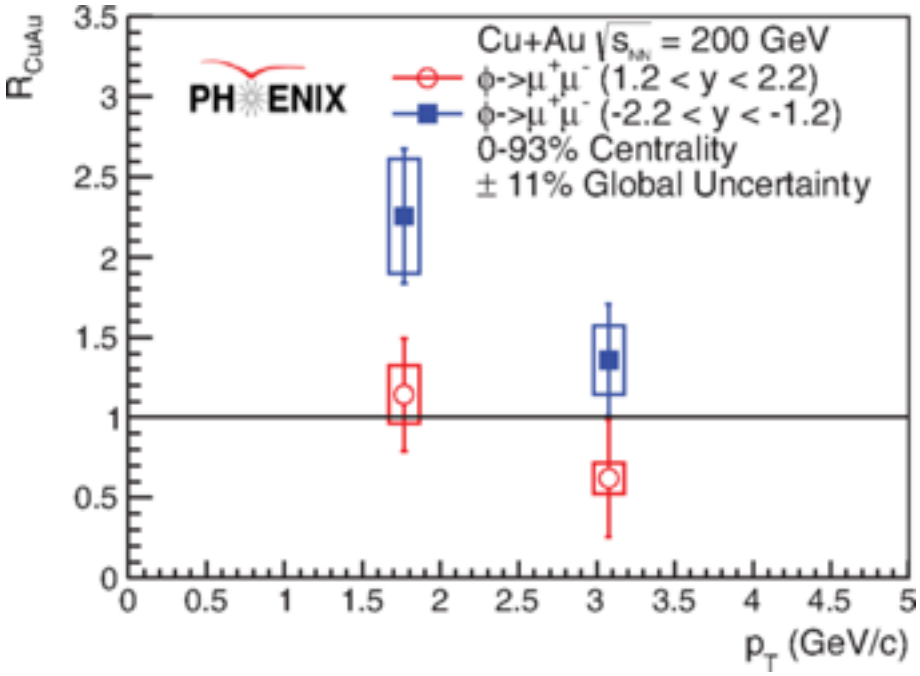
Phys. Rev. C **92**, 044909 (2015)

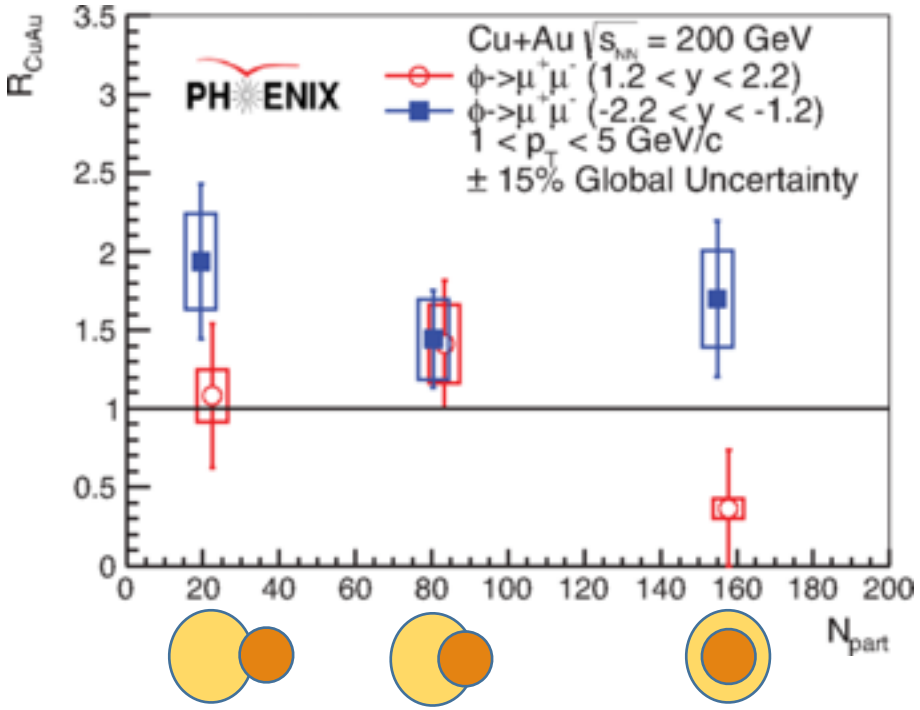


Nuclear modifications to ϕ production as a function of rapidity has similar trend as the observed in heavy flavor decay leptons. They are less suppressed in comparison with J/ψ in backward and central rapidity regions.

Nuclear Modification in Cu+Au

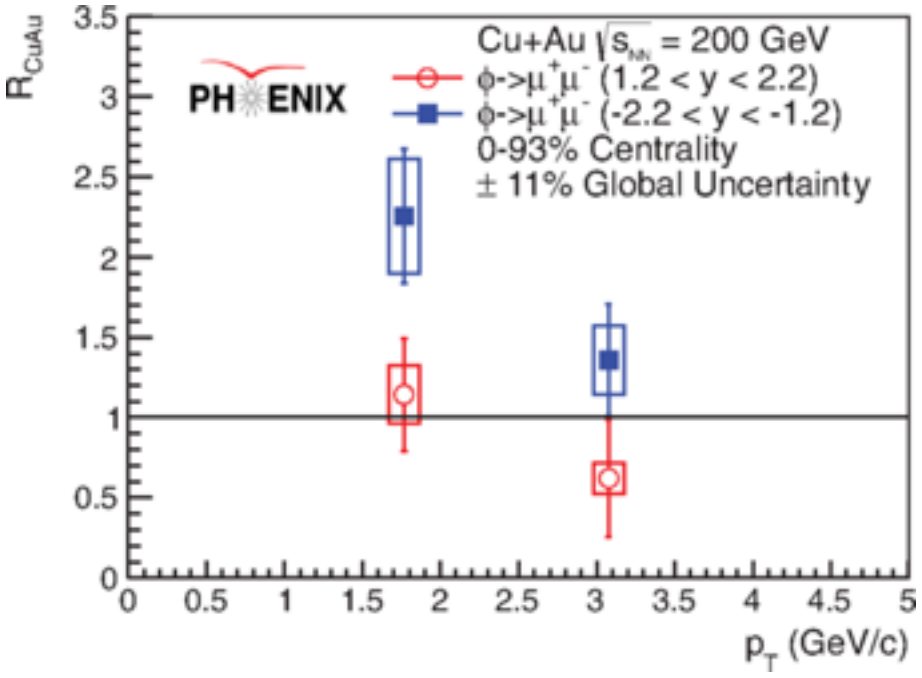
Phys. Rev. C 93, 024904 (2016)

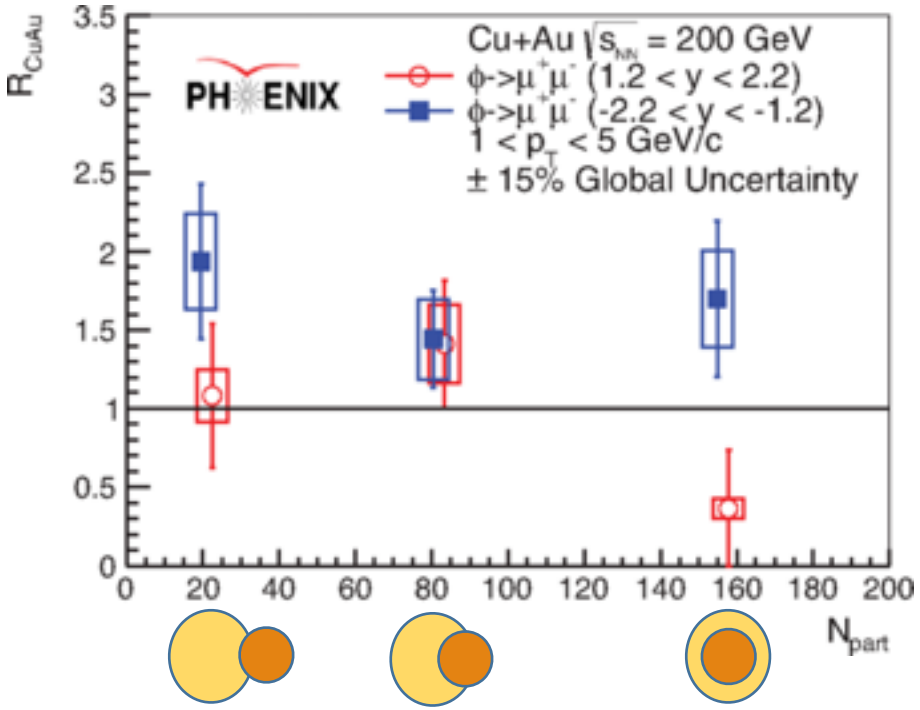




Nuclear Modification in Cu+Au

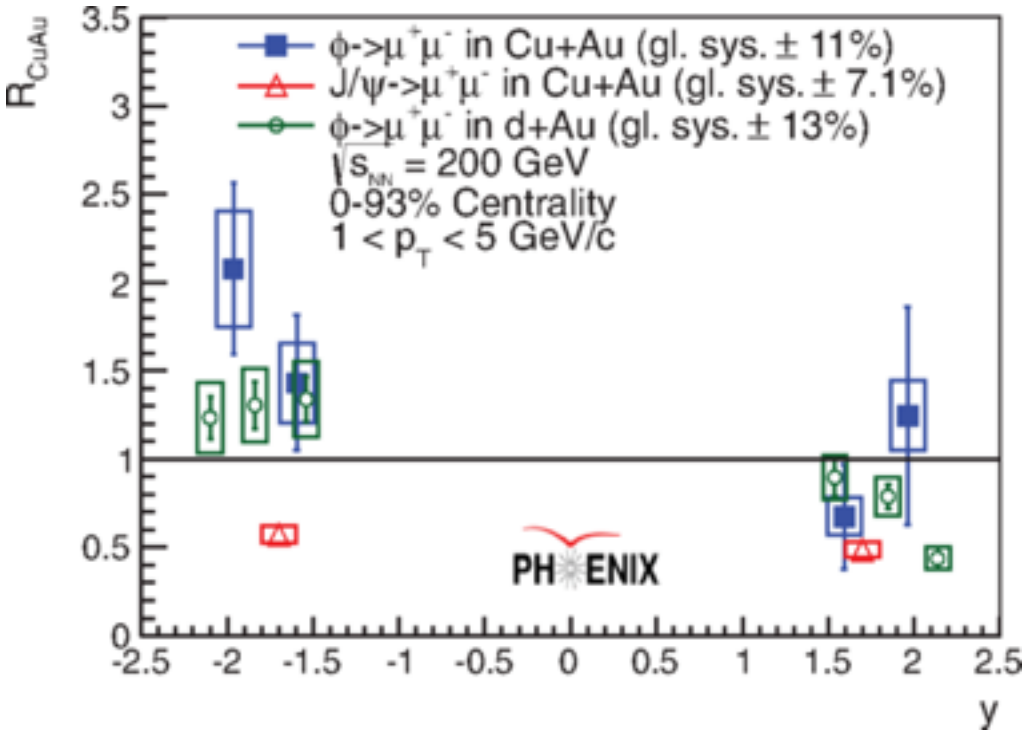
Phys. Rev. C 93, 024904 (2016)





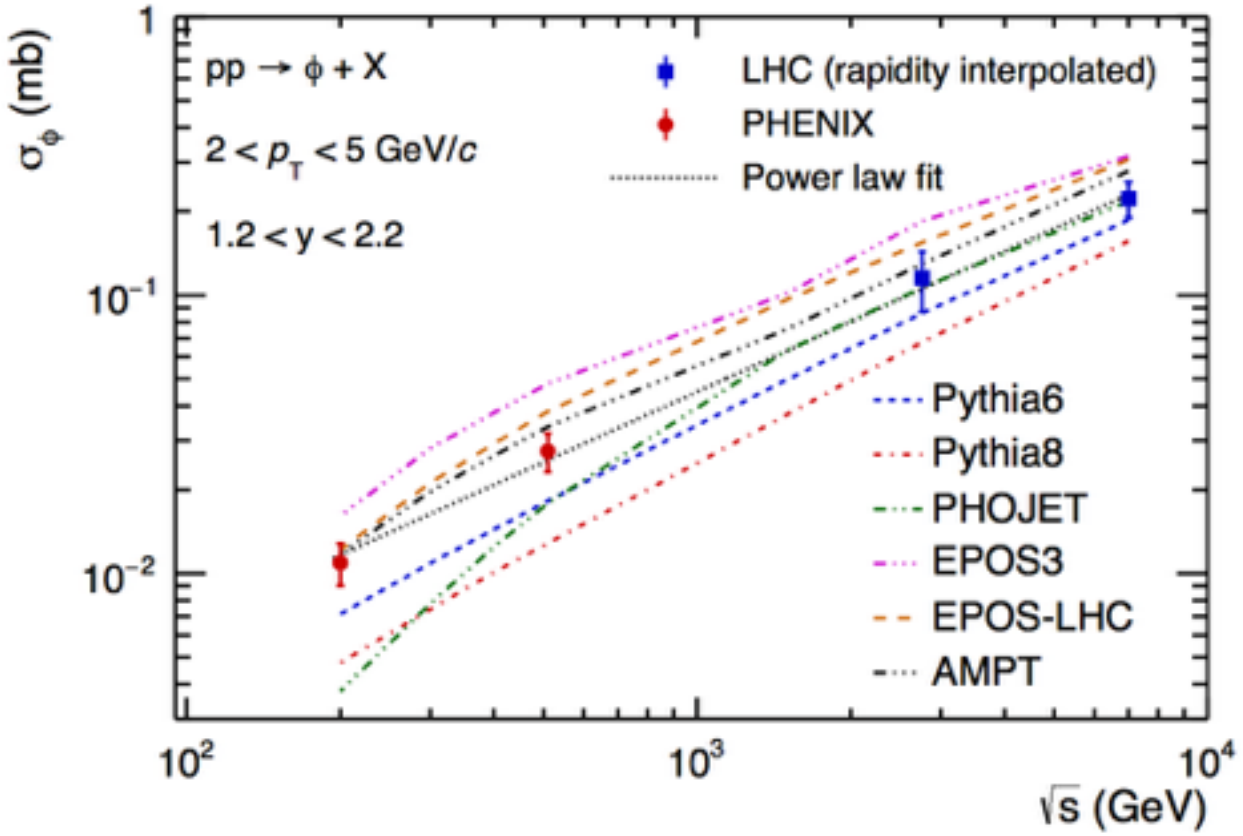
ϕ meson production is enhanced over all centralities in the Au-going direction, while a suppression is observed for the most central collisions in the Cu-going direction

ϕ Meson vs J/ψ in Cu+Au



- Integrated over all centralities, ϕ nuclear modification in Cu+Au is consistent with ϕ in *d*+Au collision.
- However, *J/ψ* is suppressed in Cu+Au both in the Cu-going and Au-going directions.

Energy Dependent ϕ Production in p+p Collisions



PHENIX is about to release a new publication about energy-dependent f production in forward/backward rapidities by combining the results published by ALICE at LHC. Extensive comparisons with Monte Carlo event generators available in the market have been done!

Summary and Outlook

- PHENIX has measured ϕ production in p+p, d+Au, Cu+Cu, Cu+Au and Au+Au collisions with a wide rapidity coverage. This talk summarizes the recent results of ϕ production in forward and backward rapidities measured with the PHENIX Muon Arms.
- The particle-dependent nuclear modifications in all colliding systems will provide stringent tests of theoretical model predictions.
- The data analysis of ϕ production in p+Al, He+Au, and Au+Au in forward and backward rapidities is ongoing and is hoped to be published soon.

Thank you all!

Nuclear Modification Factor (d+Au)